A STUDY OF THE EFFECTS OF INCREASED IODINE FEEDING TO A HERD OF SIXTY DAIRY COWS[1]

JEROME H. MEYER,[2] NORMAN L. MATTHEWS AND GEORGE M. CURTIS,

Department of Research Surgery, The Ohio State University,[3] Columbus, Ohio

It is the purpose of this paper to present the results obtained in an experiment designed to determine the effects of increased iodine feeding upon a herd of sixty dairy cows. The great number of variable factors encountered, however, prevent the drawing of any final or even of comprehensive conclusions; even from the extensive data collected.

We endeavored to conduct this experiment in as scientific a manner as possible, without too greatly disturbing the routine of the dairy. The farm employees were carefully instructed and trained in the collection of specimens. The best quantitative methods available were used. Nevertheless, it must be borne in mind that such a study as this, even at its best, cannot possibly be as accurate as an investigation using laboratory animals, or even human beings under controlled hospital conditions.

The valuable herd of dairy cows used in this experiment produces *a Grade A raw milk*, which is delivered in Columbus, Ohio.[4] It was therefore necessary to protect this privately owned dairy herd by carefully observing the cows during the entire experiment. The general health of the cows, the output of milk and the quality of milk were essential factors to be conserved. The cows had been previously tested for tuberculosis, B-abortus and mastitis.

LITERATURE

A brief review of the literature is first presented in order to consider the various effects of increased iodine feeding which have been thus far reported. Several investigators have previously used both laboratory and domestic animals, as well as hospital patients.

[1]This investigation was aided by a grant from The Iodine Educational Bureau, Inc., of New York City.

[2]William Wallace Kincaid Fellow in Research Surgery.

[3]Publication of this investigation was made possible by a Grant from The Comly Fund for Medical and Surgical Research of The Ohio State University.

[4]We express our thanks to Mr. Dan Schaaf and his coworkers for their assistance.

Marine (1) as early as 1907 stated that iodine-containing salts had been fed to Michigan sheep to prevent the high death rate ordinarily then occurring among the new-born. Ten years later Smith (2) observed the abnormal condition which he called "Fetal Athyreosis." This state in new-born pigs is characterized by an enlarged thyroid gland, thickened skin, hairlessness or weakness, and often by still-birth. Smith estimated that as many as 10,000 animals were lost annually in Montana. Kalkus (3) reported a high incidence of "Fetal Athyreosis" in horses, cattle, sheep and goats. Furthermore, breeding difficulties have also been described in pigs of North Dakota (4) and Wisconsin (5), and similar observations have been made elsewhere (6) (7).

Hanzlik (8) showed that supplemental iodine feeding is a factor in the rate of growth of laboratory animals. He observed, moreover, that rats having a diet rich in iodine maintain a better general condition than those without such a supplement.

Evvard and Culbertson (9) observed an increase in the rate of growth of domestic animals subsequent to the addition of iodine to the diet. They fed 5 milligrams, 43 milligrams and 55 milligrams of potassium iodide per day to a total of 36 pigs. The increase in the rate of growth averaged ten per cent for all the pigs even though they ate ten per cent less food. Kelly (10) reported similar results in the growth of young pigs. Weiser and Zaitschek (11) studied the size of the litter and the weight of the offspring. They fed 125 milligrams of potassium iodide per day to sows during the last three weeks of gestation and the first ten weeks of lactation. Of the non-iodized group 3.8 pigs per litter were raised whose average weight at the end of ten weeks of lactation was 13.2 kilograms. Of the iodized group 7.6 pigs per litter were raised whose average weight was 18.5 kilograms. Other investigators (12) (13) found no essential differences in the weights of pigs fed amounts of potassium iodide varying up to one gram.

The effect of increased iodine feeding upon the milk production of cows was studied by Stiner (14), Scharrer (15), Weiser and Zaitschek (11) and Thomson (16). Stiner in 1924 observed that the addition of iodine to the diet of cows resulted in an increase of milk production over controls. Scharrer and his group increased the milk yield 5–10 per cent by adding large quantities of iodine, 100 to 600 milligrams per day, to the diet of the cows. Weiser and Zaitschek obtained a seven per cent increase in milk production by feeding 125 milligrams of potassium iodide per day.

More recently Thomson (16) made a comparative study on Ayrshire cows over a period of five years. He used eight cows as controls and fed seven cows 90 milligrams of iodine per day. For the five-year period the non-iodized group produced 788 gallons of milk per cow per year while the iodized group produced only 747 gallons per year. However, a comparison of these values with those of the first year, in which the non-iodized cows produced 749 gallons and the iodized cows 626 gallons, show that the iodized cows registered larger gains. Thomson did not attempt to draw any significant conclusions from this extensive study.

The normal iodine content of cows' milk has been determined by numerous investigators. The average iodine content of milk in goitrous areas is 2.9 mcg. per cent,[5] but this result is based upon a limited number of determinations (17). Hanford, Supplee and Wilson (18) obtained average values of 6.9 in South Carolina, 3.2 in Wisconsin and 2.7 mcg. per cent in New York.

European investigators, as well as investigators in our own country, have studied the milk iodine values of cows receiving increased iodine feeding. Scharrer and Schwaibold (19) obtained milk with only 28.9 mcg. per cent iodine from cows fed 100 milligrams per day, 37 mcg. per cent for 200 milligrams fed per day, and 212 mcg. per cent for 600 milligrams fed per day. Hanford, Supplee and Wilson (18) found 25, 40.3 and 181.3 mcg. per cent on feeding 3.1, 46. 3 and 198 milligrams per day, respectively. The milk iodine of the control cows was 6.1 mcg. per cent. Orr and Leitch (20) obtained 33 mcg. per cent by feeding 180 milligrams per day whereas they obtained only 4 to 7 mcg. per cent for their control cows. McHargue (21) elevated the iodine in milk to 40 mcg. per cent by feeding iodine.

Other European investigators (22) (23) (24) have shown that the iodine content of milk from cows and milking goats increases following increased iodine feeding. None of the above investigators reports any deleterious effects from the increased iodine intake.

A previous investigation made within our group (25), using a herd of Brown Swiss Cows, showed that upon the addition of approximately 94 milligrams of iodine per day the iodine content of the milk was found to vary from 0.016 to 0.182 mcgm. per

[5]This represents 29 parts of iodine per billion of milk.

cent, which is a great increase over the normal milk iodine. A definite increase in blood iodine, urinary excreted iodine and fecal iodine was also observed. Since, however, no control cows were available, a comparative study was impossible.

METHODS

Two breeds of cows, Holstein and Guernsey, numbering 30 each, were used in this experiment. These cows were kept in their normal environment. A study of the cows was made during the Fall of 1935 and the Winter, Spring and Summer of 1936. The major portion of the study was conducted during the colder months, November to April, when the cows were kept under shelter. Later, observations were made when the cows were turned out to pasture.

Before any increased iodine feeding was instituted, it was found desirable to obtain a rough idea as to the status of the normal iodine "balance" of the cows to be studied. Blood was obtained by vena puncture from each of the sixty cows on November 19, 1935, for the determination of iodine. On December 14 to 15, 1935, and on February 15 to 16, 1936, two one-day "balance" studies were made. Representative samples for the determination of the iodine content of the feed intake (water, ensilage, alfalfa hay and a grain mix) were also obtained and analyzed.

Since the collection of specimens for the determination of iodine in the excreta required a constant attendant, only six Holstein and six Guernsey cows were studied. These were chosen at random, to represent their respective groups. Great care was exercised to obtain and record all the excreta for the 24-hour period. A representative sample of the pooled specimens of urine and feces was taken for analysis. The amount of milk yielded in the 24-hour period was carefully recorded and a composite sample of the two milkings (3:00–5:00 A. M. and 2:00–4:00 P. M.) was taken for analysis.

On February 16, 1936, the Holstein and Guernsey groups of cows were divided into two groups, each composed of 15 cows. From this time on 15 Holstein and 15 Guernsey cows were fed continually a grain mixture which contained by actual analysis 3.2 milligrams of iodine per 100 grams of feed. The Ubiko Milling Company of Cincinnati, Ohio,[6] furnished this iodized

[6]We express our thanks to the Ubiko Milling Company for its cooperation in this study.

mixture, a feed prepared as one-twenty-thousandth potassium iodide or 3.4 milligrams of iodine per 100 grams of feed. Calculations show that the iodized Holstein cows received an average of 131 mg. of iodine and the iodized Guernsey cows an average of 95 mg. of iodine per day throughout the year.

The uniodized grain mixture which was fed to the control group was obtained from the same company. This feed was essentially the same as that which had been fed both groups from December 4, 1935, to February 16, 1936.

It was expedient to duplicate the "balance" studies as of the first part of the experiment previous to the institution of increased iodine feeding. Therefore, on April 14, 1936, blood samples were again obtained from all the cows. Milk samples were obtained which were representative of the 24-hour secretion on April 17 to 18, 1936.

The third "balance" study was made on three cows for each of the four groups (non-iodized Holstein and Guernsey and iodized Holstein and Guernsey). This "balance" study was conducted as was the experiment before iodinization. From the iodized cows of both breeds, for a period of five months (June to October, 1936), composite samples of milk were obtained three mornings a week for iodine analysis.[7]

All the specimens were analyzed for iodine by means of the Matthews, Curtis and Brode method (26). This method has been carefully tested, and yields results precise to 5 per cent under ideal conditions.

The official dairy tester measured the amounts of feed that the cows were receiving on April 16, May 22, June 12, July 17, August 26, September 18 and October 15, 1936. From these measurements the average amounts of iodine received by both the Guernsey and Holstein cows in the grain mixture were calculated for these dates as 128, 67, 82, 113, 125, 120 and 118 milligrams per day, respectively.

RESULTS

The results of this experiment are best presented in table form. For convenience the non-iodized cows have been called Group I and the iodized cows Group II.

[7]The results of feeding of the iodized milk to hospital patients will be reported in a subsequent publication.

Table I presents the blood iodine values in November before supplemental iodine feeding was instituted, and in April after iodinization. Figure 1 illustrates graphically the marked elevation of the blood iodine subsequent to the increased iodine intake.

The results of the one-day "balance" studies are presented as averages and are as accurate estimations as possible. The data obtained in the three "balance" studies are shown in Table II for each of the individual cows. Table III presents the group averages of the "balance" studies which are graphically presented in Figure II.

TABLE I

BLOOD IODINE VALUES

Time of Test	Breed of Cow	Group	Number of Cows Tested	Average Amount of Iodine (in mcg.) in 100 cc. of Blood	Mean Deviation from Average
Nov., 1935	Holstein	I & II	26	4.02	.95
Nov., 1935	Guernsey	I & II	27	3.82	.77
April, 1936	Holstein	I	14	4.85	1.24
April, 1936	Holstein	II	13	57.10	12.10
April, 1936	Guernsey	I	8	6.25	2.4
April, 1936	Guernsey	II	10	55.60	9.2

The blood iodine values of the non-iodized Holstein and Guernsey cows in November, 1935, and of the iodized and non-iodized cows of both groups in April, 1936.

An attempt was made to determine whether the iodine in the iodized milk was in fat or protein combination. The fat was removed by the Rose-Gottlieb (27) method and the protein by the method of Osborne and Mendel (28). From 80 to 90 per cent of the iodine remained after removal of the fat and protein. In this respect our observations confirm those of Scharrer and Schwaibold (19), who likewise studied milk from cows fed relatively large amounts of potassium iodide. They, too, found little iodine in protein or fat combination.

Other data pertaining to milk and butter-fat production, calf records, general health of the normal control cows and iodized cows will be presented by Professor O. Erf, who has collaborated in this work.

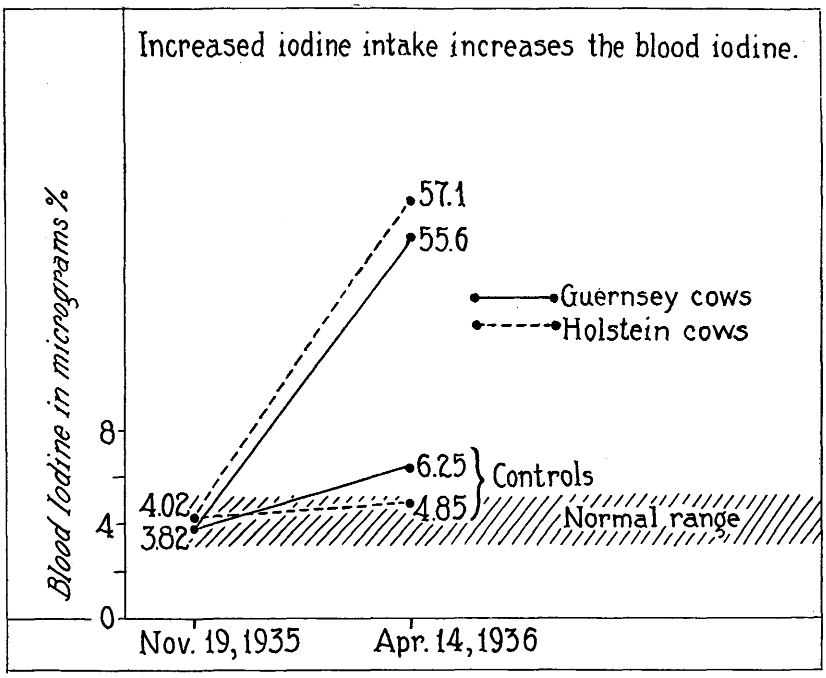

FIG. 1. Marked elevation of the blood iodine subsequent to increased iodine intake by the Holstein and Guernsey cows.

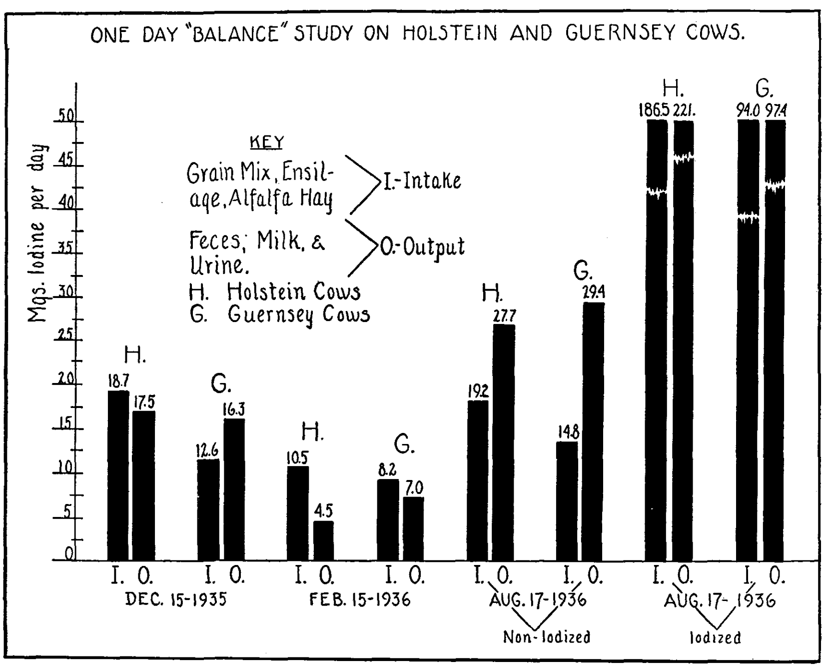

FIG. 2. A comparison of the average intake and output of iodine for iodized and non-iodized Holstein and Guernsey cows on December 15, 1935, February 15, 1936, and August 17, 1936.

TABLE II
METABOLISM STUDIES OF COWS

Date	The Number of the Cows	Breed	Estimated Food Intake Per Day							Estimated Iodine Excretion Per Day							Balance mg.
			Alfalfa Hay		Ensilage		Grain Mix		Total Iodine Intake mg.	Urine		Milk		Feces		Total Iodine Excretion mg.	
			Weight kg.	Iodine Content mg.	Weight kg.	Iodine Content mg.	Weight kg.	Iodine Content mg.		Volume liters	Iodine Content mg.	Volume liters	Iodine Content mg.	Weight kg.	Iodine Content mg.		
December 14–15, 1935	56	Holstein	7.3	2.3	15	8.0	5.5	10.2	20	8.6	2.4	19.0	2.6	45	13.0	18	+ 2
	57	"	7.3	2.3	15	8.0	4.1	7.7	18	8.6	2.4	6.6	1.9	27	8.0	12	+ 6
	59	"	7.3	2.3	15	8.0	4.5	8.5	19	9.1	2.4	8.1	4.4	41	16.0	23	— 4
	1	"	7.3	2.3	15	8.0	4.5	8.5	19	5.9	1.8	16.0	3.0	27	6.5	11	+ 8
	3	"	7.3	2.3	15	8.0	3.6	6.8	17	8.2	3.7	13.0	2.8	35	17.0	24	— 7
	5	"	7.3	2.3	15	8.0	4.5	8.5	19	5.7	1.6	15.0	1.7	37	13.0	16	+ 3
	17	Guernsey	5.5	1.7	12	6.2	2.7	5.1	13	8.2	9.8	8.3	2.1	28	15.0	27	—14
	18	"	5.5	1.7	12	6.2	2.7	5.1	13	6.4	2.9	4.5	.6	23	4.9	8	+ 5
	19	"	5.5	1.7	12	6.2	2.7	5.1	13	6.4	6.7	4.9	1.5	20	9.2	17	— 4
	42	"	5.5	1.7	12	6.2	2.3	4.3	12	7.3	3.3	1.3	.2	27	8.7	12	0
	43	"	5.5	1.7	12	6.2	2.3	4.3	12	9.5	7.5	4.1	.6	26	10.0	18	— 6
	45	"	5.5	1.7	12	6.2	2.3	4.3	12	8.2	4.6	5.4	1.5	21	8.6	15	— 3
February 15–16, 1936	56	Holstein	7.5	6.0	15	3.6	5.6	1.4	11	7.8	1.3	14.0	.3	30	2.7	4.3	+ 7
	57	"	7.5	6.0	15	3.6	1.9	.5	10	4.7	.7	3.3	.1	14	3.4	4.2	+ 6
	59	"	7.5	6.0	15	3.6	1.9	.5	10	6.9	1.0	3.1	.1	29	3.5	4.6	+ 5
	1	"	7.5	6.0	15	3.6	3.8	1.0	11	5.1	.7	15.0	.4	27	4.9	6.0	+ 5
	3	"	7.5	6.0	15	3.6	2.8	.7	10	1.8	.4	8.3	.4	23	3.4	4.2	+ 6
	5	"	7.5	6.0	15	3.6	4.7	1.2	11	4.1	.6	13.0	.4	30	4.2	5.2	+ 6
	43	Guernsey	5.6	4.5	12	2.9	4.7	1.2	9	12.0	4.5	12.0	.5	15	3.4	8.4	+ 1
	44	"	5.6	4.5	12	2.9	3.8	1.0	8	2.1	.2	11.0	.3	22	8.9	9.4	— 1
	45	"	5.6	4.5	12	2.9	3.3	.8	8	5.0	.6	9.1	.2	22	2.5	3.3	+ 5
	17	"	5.6	4.5	12	2.9	2.3	.6	8	3.6	1.6	6.4	1.2	15	5.7	8.5	— 1
	19	"	5.6	4.5	12	2.9	1.9	.5	8	3.4	.4	3.6	.5	11	3.3	4.2	+ 4
	20	"	5.6	4.5	12	2.9	2.3	.6	7	5.8	.7	6.1	.6	17	7.1	8.4	— 1

TABLE II—(Continued)

METABOLISM STUDIES OF COWS

Date	The Number of the Cows	Breed	Estimated Food Intake Per Day							Estimated Iodine Excretion Per Day							Balance mg.
			Alfalfa Hay		Ensilage		Grain Mix		Total Iodine Intake mg.	Urine		Milk		Feces		Total Iodine Excretion mg.	
			Weight kg.	Iodine Content mg.	Weight kg.	Iodine Content mg.	Weight kg.	Iodine Content mg.		Volume liters	Iodine Content mg.	Volume liters	Iodine Content mg.	Weight kg.	Iodine Content mg.		
August 17–18, 1936	56	Holstein	12.0	6.7	20.0	2.2	8.0	7.7	16.3	8.2	3.7	5.1	1.2	40	27.0	32	— 20
	57	"	12.0	6.7	20.0	2.2	12.0	11.6	20.3	13.0	.7	21.0	5.3	38	15.0	21	— 2
	58	"	12.0	6.7	20.0	2.2	12.0	11.6	20.3	20.0	5.0	11.0	4.3	40	22.0	31	— 14
	2	"	12.0	6.7	20.0	2.2	10.0	145.0	154.0	16.0	61.0	13.0	18.0	37	94.0	173	— 52
	4	"	12.0	6.7	20.0	2.2	14.0	210.0	219.0	14.0	66.0	27.0	74.0	50	157.0	297	—116
	8	"	12.0	6.7	20.0	2.2	12.0	175.0	184.0	11.0	56.0	24.0	49.0	46	87.0	192	— 11
	43	Guernsey	9.3	5.5	15.0	1.6	8.0	7.7	14.8	15.0	10.0	9.5	1.0	23	9.0	20	— 7
	44	"	9.3	5.5	15.0	1.6	8.0	7.7	14.8	10.0	40.0	4.0	.4	25	9.0	49	— 37
	45	"	9.3	5.5	15.0	1.6	8.0	7.7	14.8	13.0	5.0	9.2	2.0	23	12.0	19	— 7
	16	"	15.0	5.5	15.0	1.6	6.0	87.0	95.0	8.2	29.0	9.7	10.0	29	79.0	118	— 27
	17	"	15.0	5.5	15.0	1.6	4.0	58.0	85.0	12.0	5.0	1.0	.8	16	33.0	39	+ 40
	18	"	15.0	5.5	15.0	1.6	8.0	116.0	123.0	15.0	50.0	4.4	5.5	32	81.0	137	— 29

The intake and output of iodine of Holstein and Guernsey cows, iodized and non-iodized, on December 14–15, 1935, February 15–16, 1936, and August 17–18, 1936.

TABLE III

"BALANCE" STUDIES ON THE GROUPS OF COWS

Date	No. of Cows	Breed	Mgs. of Iodine Ingested Per Day (Averages)				Mgs. of Iodine Excreted Per Day (Averages)			
			Alfalfa Hay	Ensilage	Grain Mix	Total	Urine	Milk	Feces	Total
12-15-35	6	Holstein	2.3	8.0	8.4	18.7	2.4	2.7	12.4	17.5
12-15-35	6	Guernsey	1.7	6.2	4.7	12.6	5.8	1.1	9.4	16.3
2-15-36	6	Holstein	6.0	3.6	0.9	10.5	0.8	0.3	3.4	4.5
2-15-36	6	Guernsey	4.5	2.9	0.8	8.2	1.3	0.5	5.2	7.0
8-17-36	3	Holstein	6.7	2.2	10.3	19.2	3.1	3.4	21.0	27.7
8-17-36	3	Holstein	6.7	2.2	176.6	186.5	61.0	47.0	113.0	221.0
8-17-36	3	Guernsey	5.5	1.6	7.7	14.8	18.3	1.1	10.0	29.4
8-17-36	3	Guernsey	5.9	1.6	87.0	94.0	28.0	5.4	64.0	97.4

The average intake and output of iodine of non-iodized and iodized Holstein and Guernsey cows on December 15, 1935, January 15, 1936, and August 17, 1936.

DISCUSSION

The determination of the blood iodine of the normal cows by the Matthews, Curtis and Brode method (26) yields iodine values which approximate our values obtained for human blood by the same method. Previous to this study blood iodine values obtained by numerous investigators were, with one or two exceptions, at a much higher level. Other investigators (29) (30) (31) present values which confirm the more recent lower level. In the hands of experienced workers the newer methods have yielded iodine values which are comparable to the values obtained in this study.

The blood iodine values for the Holstein cows previous to increased iodine feeding averaged 4.02 mcg. per 100 cubic centimeters of blood, while those of the Guernsey cows averaged 3.82 mcg. per 100 cubic centimeters of blood. This slight difference is probably not significant. In the April study the blood iodine values of the non-iodized cows were higher than in the November study. These higher values may be due to a slight contamination of the feed or to a seasonal variation; on the other hand, they may not be significantly different from those obtained in November in view of the large average mean deviations and the smaller numbers of non-iodized cows in April, one-half those in November.

The blood iodine values of the iodized cows were approximately ten times higher than those of the non-iodized cows. The increase in the amount of iodine in the blood of iodized cows with respect to the non-iodized cows of both groups in November is of the order of 1300 per cent and approximately the same for the Holstein and Guernsey cows. With respect to Group I in April, the per cent increase is of the order of 1000. This illustrates the effectiveness of the amount of iodine being fed in reaching the blood stream, and consequently in maintaining a much higher level of available iodine for utilization by the body.

In a former study within our group the blood iodine of the iodized cows averaged 54.9 mcg. per 100 cubic centimeters of blood, a value comparable with values obtained in this study; 55.6 mcg. per cent for Guernsey and 57.1 mcg. per cent for the Holstein cows.

During the month of April the milk iodine reflected to a greater degree than the blood iodine the different levels of iodine fed to the two groups.

The data of the "balance" studies is only approximate, since accurate estimations of food intake, the obtaining of representative samples of food for analysis and the collection of excreta were difficult. The amount of iodine ingested in the water was considered negligible since the iodine content of the water was found to be only 0.5 mcg. per cent.

The December "Balance" Study

In the December study the six Holstein and the six Guernsey cows were nearly in balance. The average iodine intake for the Holstein cows, the greater part of which was found in the grain mixture, was 18.7 milligrams per day. The average output was 17.5 milligrams per day, which is only 1.2 milligrams below the intake. The greatest channel of excretion was the feces. The Guernsey cows during the same period were also nearly in balance. The average iodine intake of 12.6 mg. was below that of the Holstein cows. The output of 16.3 milligrams per day was lower than the output recorded by the Holstein cows, being 17.5, and only 3.7 milligrams per day above the intake. Here again the largest amount of iodine was excreted by way of the feces. Both the Holstein and Guernsey cows received most of their iodine from the ensilage and grain mixture.

The February "Balance" Study

In the February study the Holstein cows were in positive balance. The average iodine intake was 10.5 milligrams per day, 6.0 milligrams above the output. The Guernsey cows during this period were approximately in balance, the average iodine intake of 8.2 milligrams per day being 1.2 milligrams per day above the average output of 7.0 milligrams per day.

The February "balance" was on the whole at a lower level than the December "balance"; both the intake and the output of the Holstein and Guernsey cows were on a lower level. Whereas the ensilage and grain mixture each furnished the largest amounts of iodine in December, the alfalfa hay was the chief source in February. The feces, as in the December study, was the largest channel of excretion of iodine.

The August "Balance" Study

The August "balance" study for a period of increased iodine feeding shows a quite different picture. Of both the non-iodized cows and the iodized cows, Guernsey and Holstein, all but one were in negative balance. This negative balance averages 12 milligrams and 17 milligrams per cow, respectively, for the non-iodized Holstein and Guernsey cows of the controls. The non-iodized Holstein cows showed an intake of 19.1 milligrams per day and an output of 27.7 milligrams per day. The non-iodized Guernsey cows were in still greater negative balance, showing an intake of 14.8 milligrams per day and an output of 29.4 milligrams per day. Of the iodized cows the Holstein average intake was 186 milligrams per day and the output 221 milligrams. The iodized Guernsey intake was 94 milligrams per day and the output averaged 97.4 milligrams per day. The ratios of intake to output for the month of August are slightly less than 1.0, in all cases but one, in contrast to the ratios for December and February, which are in general slightly greater than 1.0.

The differences between intake and output are greater for iodized cows and therefore more negative. However, a comparison of ratios will show that it is impossible to say that either the iodized cows or the non-iodized cows were in greater negative balance. It is true, though, that for a greater iodine intake there was a greater output. In actual figures the iodine output of the iodized cows was seven to nine times that of the non-iodized cows in the case of the Holsteins, but only three to four times in the case of the Guernseys. The feces was again found to be the predominant channel of excretion of iodine for both the Holstein and the Guernsey cows.

The iodine intake of the cows during this period of pasturage varied greatly. The alternating drought and rain varied both the amount of exercise the cows obtained and the amount of food consumed. When pasturage was available, less feed and more grass was consumed. The reverse was true when none was available. Of all the feeds the grain mixture at this time contained the highest concentration of iodine.

The great negative balance of the cows may be due to (1) increased consumption of unaccountable iodine; (2) increased activity of the cows during pasturage; (3) continued excretion of iodine previously ingested in larger amounts.

To explain the great variation of the composite milk samples collected during the mid-year, the following facts must be considered. During the late spring and early summer the pasturage was abundant. Simultaneously iodized cows were fed lesser amounts of grain mixture containing added potassium iodide. In midsummer the grass in the pastures became scarce because of the extensive drought. Beginning late in June the cows were fed larger amounts of grain mixture.

An average analysis of a few grains and hays in goitrous regions yielded a result of 30 mcg. per cent (32). Forbes et al (13) found only 10 mcg. per cent in Pennsylvania. Remington and Supplee (33) found an average of 45 mcg. per cent for hog feed in South Carolina.

Ohio is generally considered to be a goitrous region. Several factors, however, may vary the iodine content of the plants of the pasture. Commercial fertilizer has been shown by investigators (20) to increase the iodine content of plants. Also, the feces of the cows, especially those receiving increased iodine feeding, would be a source of iodine for the plants.

Our determinations in February on the milk iodine values of our control cows were similar to those of other investigators mentioned in the literature. Those in April on the non-iodized cows were slightly higher. Those in December and in August were much higher.

The values of the iodine content of the milk of the iodized cows contrast with those obtained by authors mentioned in the literature. Our values for Holstein and Guernsey cows in April were 203 mcg. and 149 mcg. per cent respectively, and beginning

May 23 they averaged 80 mcg. per cent for the five months midyear (34).

The effectiveness of the use of milk containing increased iodine as a goiter prophylactic has been demonstrated both for man (35) and for experimental animals (36).

SUMMARY

Since this study, unlike our previous investigation, involved a control group of both breeds of cows used, several features of the increased iodine feeding may be noted.

No deleterious effects of the increased iodine feeding were detected. The iodized cows were apparently in as good health as the non-iodized cows.

The iodized cows were found to have blood iodine values ten times that of the control cows, a difference approximately of the order of 1000 per cent. It should be noted that the blood iodine values of the control cows are comparable to the values obtained for normal human blood.

In the "balance" studies an outstanding feature is that increased iodine feeding to dairy cows results in increased iodine content of the milk. Variations, however, do occur in the ratio of iodine in the milk to the total amount of iodine ingested. Where the iodine content ingested is increased tremendously, the increase in iodine in the milk may be even far greater than that expected from the consideration of a direct proportion. The dependence of the amount of iodine in the milk upon the amount of iodine in the food is thus firmly established. The amount of iodine in the milk seems to be independent of the volume of milk produced by the cow.

On high iodine intake the iodine in the milk is much greater than the iodine in the blood; on low iodine intake the iodine in the milk may be below the normal value.

The ratio of iodine intake to output is in all cases approximately equal to 1.0, being greater than 1.0 for the months of December and February and slightly less than 1.0 in August, a month in which the balance was consistently negative. The feces was in all cases the chief channel of excretion of iodine, approximately 70 per cent of the output of iodine being through this channel.

Feeds of the control cows were found to be considerably higher in iodine content than those reported from other goitrous regions. Similarly, milk from these cows was found to contain a larger concentration of iodine.

BIBLIOGRAPHY

(1) **Marine, D.** (1907.) On the Occurrence and Physiological Nature of Glandular Hyperplasia of the Thyroid (Dog and Sheep) together with Remarks on Important Clinical (Human) Problems. Johns Hopkins Hosp. Bul., 18: 359.

(2) **Smith, G. E.** (1917.) Fetal Athyreosis. Jour. Biol. Chem., 29: 215.

(3) *a*. **Kalkus, J. W.** (1920.) Goiter and Associated Conditions. Wash. Agr. Sta. Bul. 156.

b. Cf. Wash. Agr. Exp. Sta. Ann. Rep., 25: 42, 1915.

(4) **Shepperd, J. H.** (1929.) The Northern Pig, Its Habits, Breeding and Management. North Dakota Agr. Exp. Sta. Bul., 230: 23.

(5) **Hart, E. B.,** and **A. Sienbach.** (1918.) Hairless Pigs, the Cause and Remedy. Wis. Agr. Exp. Sta. Bul. 297.

(6) **Mills, R. H.** (1934.) Calf Losses Due to Iodine Deficiency. Jour. Am. Vet. Med. Assoc., 85: 645.

(7) *a*. **Welch, H.** (1917.) Hairlessness and Goiter in Newborn Domestic Animals. Mont. Agr. Exp. Sta. Bul., 119.

b. **Welch, H.** (1925.) Potassium Iodide in Congenital Goiter. Vet. Med., 16: (I), 26.

(8) **Hanzlik, P. J., E. P. Talbot,** and **E. E. Gibson.** (1928.) Continued Administration of Iodide and Other Salts. Arch. Int. Med., 42: 579.

(9) **Evvard, J. M.,** and **C. C. Culbertson.** (1925.) Potassium Iodide Feeding Beneficial to Young Swine. Res. Bul., Iowa Agr. Exp. Sta., 86: 183.

(10) **Kelly, F. C.** (1925.) The Influence of Small Quantities of Potassium Iodide on the Assimilation of Nitrogen, Phosphorus and Calcium in the Growing Pig. Biochem. Jour., 19: 559.

(11) **Weiser, S.,** and **H. Zaitschek.** (1927.) Zur Biochemie des Jods. Biochem. Z., 187: 377.

(12) **Crichton,** cited by Orr, J. and I. Leitch (20), pp. 36–37.

(13) **Forbes, E. B., G. M. Karns, S. I. Beckdel, P. S. Williams, T. B. Keith, E. W. Collenbach** and **R. R. Murphy.** (1932.) The Value of Iodine for Livestock in Central Pennsylvania. Jour. Agr. Res., 45: 111.

(14) **Stiner.** (1924.) Bul. I. eidgenoss. Gesundheitsamtes 1924, cited by Orr and Leitch (20), p. 11.

(15) *a*. **Scharrer, K.** and **W. Schropp.** (1929.) Zur Kenntnis des Jods als biogenes Element. XXII. Mitteilung: Futterungsversuch mit steigenden Jodgaben an Milchkuhen. Biochem. Z. 213: 18.

b. **Schropp, W.** (1929.) Zur Kenntnis des Jods als biogenes Element. XXI. Mitteilung: Futterungsversuch mit Jod an Milchkuhen. Biochem. Z., 213: 1.

(16) **Thomson, W.** (1934.) The Effect of Iodine Supplement in the Ration of Dairy Cows. Vet. J., 90: 49.

(17) **Orr, J.,** and **I. Leitch** (20), p. 27.

(18) **Hanford, Z. M., G. C. Supplee,** and **L. T. Wilson.** (1934.) The Iodine Content of Milk as Affected by Feeding Iodized Dry Milk. Jour. Dairy Sci., 17: 771.

(19) **Scharrer, K.** and **W. Schwaibold.** (1929.) Zur Kenntnis des Jods als biogenes Element. XXII. Mitteilung: Fortgesetzte Untersuchungen über den Chemismus des truschen Jodstoffwechsels. Biochem. Z., 213: 32.

(20) **Orr, J.** and **Leitch.** (1929.) Iodine in Nutrition. Medical Research Council, Special Report Series, 123: 27.

(21) **McHargue, J. S.** (1934.) Iodine Content of Corn Produced in 19 Eastern Kentucky Counties. Ky. Agr. Exp. Sta., 46th Ann. Rep., 1933: 44–45.

(22) **Strobel, H., K. Scharrer,** and **W. Schropp.** (1927.) Zur Kenntnis des Jods als biogenes Element. VII. Mitteilung: Futterungsversuche mit verschiedenen Jodgaben an Milchkuhen. Biochem. Z., 180: 313.

(23) **Niklas, H., J. Schwaibold** and **K. Scharrer.** (1926.) Zur Kenntnis des Jods als biogenes Element. II. Mitteilung: Futterungsverusch mit Steigenden Jodgaben zu Milchziegen. Biochem. Z., 170: 277.

(24) **Scharrer, K.** and **J. Schwaibold.** (1927.) Zur Kenntnis des Jods als biogenes Element. VI. Mitteilung: Uber den Chemismus des tierschen Jodstoffwechsels. Biochem. Z., 180: 307.

(25) **Phillips, F. J., O. Erf,** and **George M. Curtis.** (1935.) The Effects of Prolonged Increased Iodine Feeding. Ohio Jour. Sci., 35: 286.
(26) **Matthews, N. L., George M. Curtis** and **W. R. Brode.** (1938.) The Determination of Iodine in Biological Materials. Ind. Eng. Chem., Anal. Ed., 10: 612.
(27) **Woodman, A. G.** (1931.) Food Analysis. McGraw-Hill Book Co., Inc., New York and London, p. 119.
(28) **Osborne, T. B.,** and **L. B. Mendel.** (1911.) Feeding Experiments with Isolated Food Substances. Part II. Carnegie Institute of Washington, p. 80.
(29) **Puppel, I. D.** and **George M. Curtis.** (1938.) Iodine Balance in Exophthalmic Goiter. Arch. Path., 26: 1093–1120.
(30) **Decourcy, J. L., C. D. Stevens, R. Weiskittel** and **N. Brower.** (1938.) The Effects of Ligation of the Common Bile Duct on the Blood Iodine and Blood Counts of Male Rabbits. Jour. Lab. and Clin. Med., 23: 1037–1046.
(31) **Orr, J.** and **I. Leitch** (20), p. 24.
(32) **Orr, J.** and **I. Leitch** (20), p. 87.
(33) **Remington, R. E.** and **G. C. Supplee.** (1934.) Studies of Iodine Content of Milk. II. Variation in Mixed Milk of Herds. J. Dairy Science, 17: 19.
(34) **Matthews, N. L., George M. Curtis** and **J. H. Meyer.** (1939.) The Effect of Increased Iodine Feeding Upon the Iodine Content of Cows' Milk. J. Dairy Research. Jour. Dairy Research, 10: 395–402.
(35) **Orr, J. B.** and **I. Leitch** (20), p. 9.
(36) **Kraus, W. C.,** and **C. F. Monroe.** (1930.) A Comparison of the Influence of Iodized Milk and of Potassium Iodide Administered Directly on the Size and Iodine Content of the Thyroid Gland of Rats. Jour. Biol. Chem., 89: 581.